



## Physical Sciences

### Integrity Monitoring of Mercury Discharge Lamps

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Mercury discharge lamps are critical in many trapped ion frequency standard applications. An integrity monitoring system can be implemented using end-of-life signatures observed in operational mercury discharge lamps, making it possible to forecast imminent failure and to take action to mitigate the consequences (such as switching to a redundant system). Mercury lamps are used as a source of 194-nm ultraviolet radiation for optical pumping and state selection of mercury trapped ion frequency standards. Lamps are typically fabricated using  $^{202}\text{Hg}$  distilled into high-purity quartz, or other 194-nm transmitting material (e.g., sapphire). A buffer gas is also placed into the bulb, typically a noble gas such as argon, neon, or krypton.

The bulbs are driven by strong RF fields oscillating at  $\approx 200$  MHz. The lamp output may age over time by two internal mechanisms: (1) the darkening of the bulb that attenuates light transmission and (2) the loss of mercury due to migration or chemical interactions with the bulb surface. During fabrication, excess mercury is placed into a bulb, so that the loss rate is compensated with new mercury emanating from a cool tip or adjacent reservoir. The light output is nearly constant or varies slightly at a constant rate for many months/years until the mercury source is depleted. At this point, the vapor pressure abruptly falls and the total light output and atomic clock SNR (signal-to-noise ratio) decrease. After several days to weeks, the light levels decrease to a point

where the atomic clock SNR is no longer sufficient to stay in lock, or the lamp self-extinguishes.

This signature has been observed in four separate end-of-life lamp failures while operating in the Deep Space Network (DSN). A simple integrator circuit can observe and document steady-state lamp behavior. When the light levels drop over a predetermined time interval by a specified amount (e.g., 20 percent), an alarm is set. For critical operational applications, such as the DSN or in space flight, this warning provides notice that a failure may be imminent, and for operators or control algorithm to take action.

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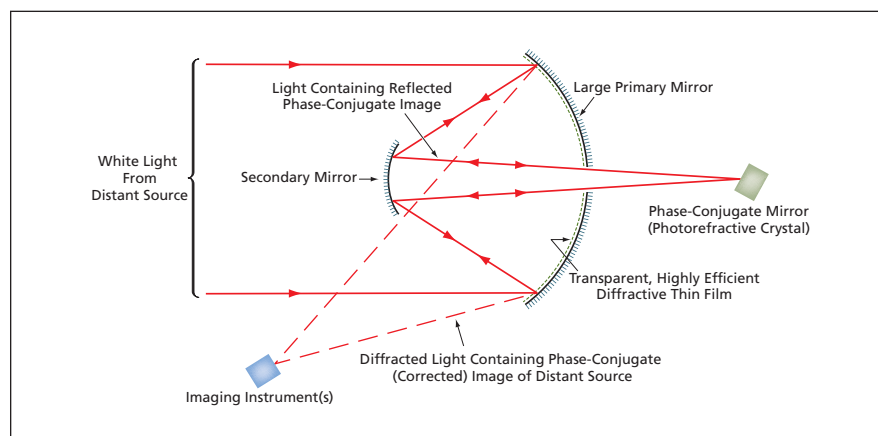
### White-Light Phase-Conjugate Mirrors as Distortion Correctors

**Optical aberrations of large optical components could be corrected relatively inexpensively.**

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White-light phase-conjugate mirrors would be incorporated into some optical systems, according to a proposal, as means of correcting for wavefront distortions caused by imperfections in large optical components. The proposal was given impetus by a recent demonstration that white, incoherent light can be made to undergo phase conjugation, whereas previously, only coherent light was known to undergo phase conjugation.

This proposal, which is potentially applicable to almost any optical system, was motivated by a need to correct optical aberrations of the primary mirror of the Hubble Space telescope. It is difficult to fabricate large optical components like the Hubble primary mirror and to ensure the high precision typically required of such components. In most cases, despite best efforts, the components as fabricated have small imperfections that introduce optical aberrations that adversely affect imaging quality.



A **Phase-Conjugate Mirror** would be added to a conventional primary-and-secondary-mirror telescope in the position ordinarily occupied by the imaging instrument(s). A transparent diffractive thin film would also be added to the primary mirror. The phase-conjugate (corrected) image would be diffracted onto the repositioned imaging instruments.

Correcting for such aberrations is difficult and costly. The proposed use of white-light phase conjugate mirrors offers a relatively simple and inexpensive solution of the aberration-correction

problem. Indeed, it should be possible to simplify the entire approach to making large optical components because there would be no need to fabricate those components with extremely high

precision in the first place: A white-light phase-conjugate mirror could correct for all the distortions and aberrations in an optical system. The use of white-light phase-conjugate mirrors would be essential for ensuring high performance in optical systems containing lightweight membrane mirrors, which are highly deformable.

As used here, “phase-conjugate mirror” signifies, more specifically, an optical component in which incident light undergoes time-reversal phase conjugation.

In practice, a phase-conjugate mirror would typically be implemented by use of a suitably positioned and oriented photorefractive crystal. In the case of a telescope comprising a primary and secondary mirror (see figure) white light from a distant source would not be brought to initial focus on one or more imaging scientific instrument(s) as in customary practice. Instead, the light would be brought to initial focus on a phase-conjugate mirror. The phase-conjugate mirror would send a phase-conjugate image back, along the path of the incoming light, to the primary mirror. A transparent, highly efficient diffractive thin film deposited on the primary mirror would direct the phase-conjugate image to the imaging instrument(s).

This work was done by Donald Frazier and W. Scott Smith of Marshall Space Flight Center, Hossin Abdeldayem of Goddard Space Flight Center, and Partha Banerjee of the University of Dayton. For further information, contact Hossin Abdeldayem at [hossin.a.abdeldayem@nasa.gov](mailto:hossin.a.abdeldayem@nasa.gov). MFS-31683-1

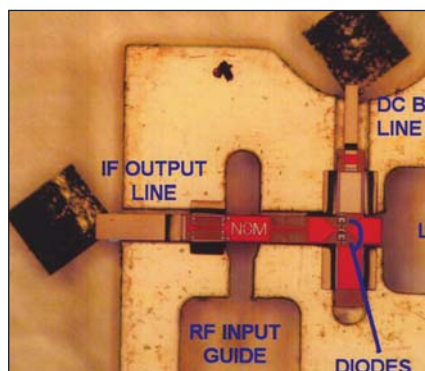
## Biasable, Balanced, Fundamental Submillimeter Monolithic Membrane Mixer

**Gallium arsenide membrane technology enables wide bandwidth and high operating frequencies.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

This device is a biasable, submillimeter-wave, balanced mixer fabricated using JPL's monolithic membrane process — a simplified version of planar membrane technology. The primary target application is instrumentation used for analysis of atmospheric constituents, pressure, temperature, winds, and other physical and chemical properties of the atmospheres of planets and comets. Other applications include high-sensitivity gas detection and analysis. This innovation uses a balanced configuration of two diodes allowing the radio frequency (RF) signal and local oscillator (LO) inputs to be separated. This removes the need for external diplexers that are inherently narrowband, bulky, and require mechanical tuning to change frequency. Additionally, this mixer uses DC biasability to improve its performance and versatility.

In order to solve problems relating to circuit size, the GaAs membrane process was created. As much of the circuitry as possible is fabricated on-chip, making the circuit monolithic. The remainder of the circuitry is precision-machined into a waveguide block that holds the GaAs circuit. The most critical alignments are performed using micron-scale semiconductor technology, enabling wide bandwidth and high operating frequencies.



In the **Balanced Mixer**, the diodes are at the right side of the circuit and the LO comes from the waveguide at the right into a reduced-height section containing the diodes. The RF signal is picked up from the RF waveguide by the probe on the left, and flows rightward to the diodes.

The balanced mixer gets superior performance with less than 2 mW of LO power. This can be provided by a simple two-stage multiplier chain following an amplifier at around 90 GHz. Further, the diodes are arranged so that they can be biased. Biasing pushes the diodes closer to their switching voltage, so that less LO power is required to switch the diodes on and off.

In the photo, the diodes are at the right end of the circuit. The LO comes

from the waveguide at the right into a reduced-height section containing the diodes. Because the diodes are in series to the LO signal, they are both turned on and off simultaneously once per LO cycle. Conversely, the RF signal is picked up from the RF waveguide by the probe at the left, and flows rightward to the diodes. Because the RF is in a quasi-TEM (suspended, microstrip-like) mode, it impinges on the diodes in an anti-parallel mode that does not couple to the waveguide mode. This isolates the LO and RF signals. This operation is similar to a cross-bar mixer used at low frequencies, except the RF signal enters through the back-short end of the waveguide rather than through the side. The RF probe also conveys the down-converted intermediate frequency (IF) signal out to an off-chip circuit board through a simple LC low-pass filter to the left as indicated. The bias is brought to the diodes through a bypass capacitor at the top.

This work was done by Peter Siegel, Erich Schlecht, Imran Mehdi, John Gill, James Velebir, Raymond Tsang, Robert Dengler, and Robert Lin of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-44698